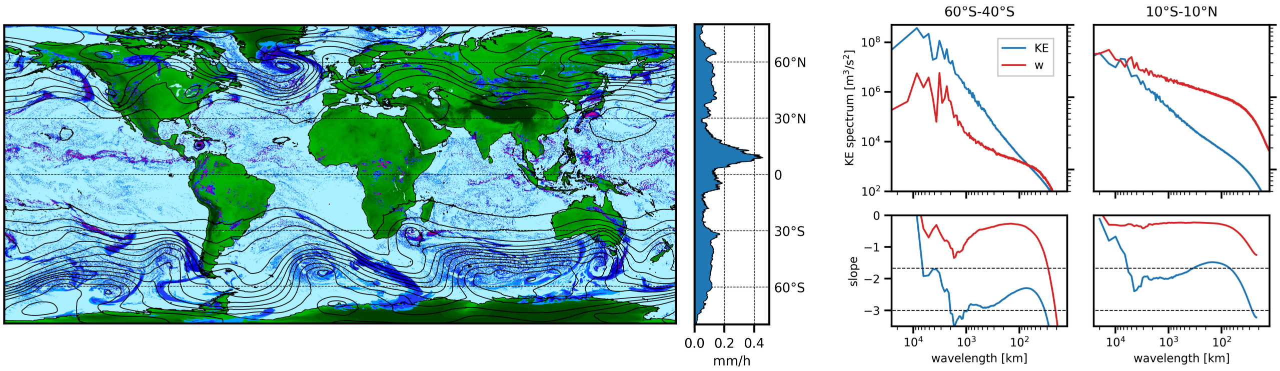
Spectral Analysis of Global High-Resolution Simulations

A key characteristic of atmospheric circulation is its kinetic energy spectrum. According to turbulence theory, this spectrum follows power-law relationships with respect to the wavenumber. Observational studies have identified two main regimes: a −3 slope at spatial scales between approximately 4000 km and 400 km, and a −5/3 slope at scales below 400 km. However, analyses of model output over Germany have revealed substantial flow-dependent variability in the mesoscale kinetic energy spectrum, primarily associated with precipitation processes (Selz et al., 2019). Estimating the local variability of the kinetic energy spectrum from global datasets remains challenging. Spherical harmonic transformations are inherently global, while local approaches based on running windows provide only approximate solutions. Global wavelet transforms, although promising, are computationally complex and difficult to implement.



The figure shows on the left a snapshot of convection-permitting model simulation (ICON, precipitation and 500hPa geopotential) and on the right a basic spectral analysis of the kinetic energy and the vertical wind.

In this master's thesis, an alternative approach is proposed that applies global spherical harmonic transformations to masked datasets. To minimize artifacts and spectral leakage caused by the mask geometry, it is essential to optimize the mask design. Such optimization techniques have been widely used in geophysics and astronomy for analyzing incomplete spherical data (Wieczorek and Simons, 2005, 2007; Simons et al., 2006). Since there are no fundamental constraints on mask shape, masks can be derived from atmospheric features such as precipitation patterns, land–sea distribution, or ensemble variability. This methodology offers a novel way to investigate the relationships between local variations in the kinetic energy spectrum and meteorological processes like precipitation intensity, orographic flow and uncertainty growth.

This master project requires strong knowledge of mathematics and atmospheric dynamics, as well as solid programming skills.

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